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Aerospace Technology Division
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FOREWORD

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PAPERS

SOVIET RESEARCH ON SEMICONDUCTING POLYMERS. II. IRRADIATED AND HEAT-TREATED POLY(VINYL ACETATE)

by Serge Markov

SUMMARY: A new semiconducting polymer, irradiated and heat-treated poly(vinyl acetate), has recently been developed in the Soviet Union. The research on this new material has involved preparation, study of its electrical and paramagnetic properties, study of the effect of subsequent irradiation on these properties, and the development of an electrical conduction mechanism.

Soviet research in the area of semiconducting polymers, which began around 1958-1959, has been steadily increasing in scope and tempo. As is known, semiconducting polymers can be prepared in two main ways: 1) synthesis from the monomers, and 2) modification of existing dielectric polymers by treatments such as pyrolysis and/or irradiation. Reviews of various materials prepared by both routes have appeared in special reports.* A detailed review of Soviet research on heat-treated polyacrylonitrile appeared in this journal** and a review on irradiated and heat-treated polyethylene was published in the Soviet journal, *Uspekhi khimii* [1].***

In March 1966, the preparation at the Institute of Electrochemistry, AS USSR, of a new semiconducting polymer with a high degree of structural regularity, by treatment of poly(vinyl acetate) (PVA) with ionizing radiation and heat, was listed among the outstanding recent achievements of Soviet science in the annual report of the Main

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*ATD Reports 66-35, 66-49, and 66-84.
**FSB, v. 2, no. 2, Feb 1966, 8-25.
***Available in English translation.

Secretary of the Presidium of the Academy of Sciences [2]. Since then, a series of articles on the synthesis and properties of the new materials have appeared in the Soviet literature. A survey of these papers reveals that a research program on irradiated and heat-treated PVA is currently in progress at the above-mentioned Institute, apparently under the guidance of N. A. Bakh and A. V. Vannikov. The research conducted thus far has concerned the preparation, the electrical and paramagnetic properties of the material, the effect of subsequent irradiation on these properties, and the development of an electrical conduction mechanism which may be applicable to other semiconducting polymers.

As was previously shown in the case of polyethylene, irradiation followed by heat treatment makes it possible to convert a dielectric polymer into an organic semiconductor whose properties vary widely depending on the conditions of the treatment. In the case of polyethylene, the step of low-temperature oxidation with molecular oxygen, which immediately follows the irradiation, plays an important part in the chemical processes which give rise to the required conjugated structures. The choice of PVA as the material to be modified was initially prompted by interest in determining to what extent the appropriate reactions may be ensured by the oxygen which is part of the initial polymer. In PVA the regular alternation of acetate groups and hydrogen was expected to provide additional information as to the mechanism of structural changes occurring as a result of modification.

The first full-size paper [3] concerning the new material dealt with its electrical properties. Powder and film specimens were used in the electrical measurements. The powder materials were prepared by a method similar to that used earlier [4] for polyethylene. Film specimens were deposited from cold solutions in toluene onto substrates having predeposited gold electrodes. Ac and dc electrical measurements were conducted in vacuum.

In the case of powder specimens, most results were obtained for PVA irradiated with 5 Mev electrons to an absorbed dose of 5.6×10^{23} ev/g. As in the case of polyethylene, the conductivity of irradiated and heat-treated PVA is an exponential function of ambient temperature in the range -70 to 150° C; its thermoelectric power is independent of ambient temperature in the range +20 to 150° C and indicates p-type conduction. Table 1 gives numerical values of conductivity ($\sigma_{20^\circ C}$), thermoelectric power (α) and activation energy for conduction (ΔE) for specimens prepared at different heat-treatment temperatures (HTT). As Table 1 indicates, with increasing HTT, room temperature conductivity increases while activation energy and thermoelectric power decrease.

It was of interest to compare the electric properties of semiconducting materials from PVA and polyethylene. Figure 1 shows HTT, activation energy and thermoelectric power as a function of room temperature electric conductivity for these two materials. As the figure indicates, in the case of PVA, the same conductivity occurs at lower HTT, and higher thermoelectric powers and lower activation energies correspond to the same conductivities. For a given HTT, the effectiveness of modification increases with irradiation dose. Table 2 illustrates this effect of dose for specimens with the same HTT of 620° C.

In the case of films, dc measurements were conducted with specimens in the form of surface and multi-layered cells. Table 3 shows (see Table 1) that the dependence of electrical conductivity and activation energy on HTT is generally in good agreement for powder and film specimens. The frequency dependence of ac conductivity (shown in Figure 2) was measured for surface cells. As Figure 2 indicates, conductivity is independent of frequency up to 20 MHz for specimens with HTT>620° C. However, for the sample with an HTT of 620° C, dc conductivity and ac conductivity in the range 10—20 MHz differ by three orders of magnitude.

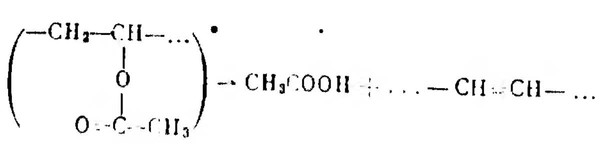
The differences in the electrical properties of the two materials were attributed to the fact that, in the case of PVA, the conjugated regions are more extensive and ordered than in the case of polyethylene.

These early results showed that irradiation coupled with heat treatment of PVA produces materials with properties close to those of materials based on polyethylene, and that constitutional oxygen is capable, within certain limits, of ensuring oxidative dehydrogenation. The better electrical properties of products from PVA, as compared to those from polyethylene are apparently due to more favorable conditions for the formation of conjugated structures in the case of PVA.

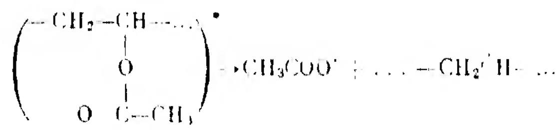
The next step was to study the new PVA materials by EPR spectroscopy [5]. The preparative method used for the samples was the standard three-step procedure previously developed [1] for polyethylene: 1) irradiation of PVA samples in vacuum; 2) two-hour heat treatment in air at 250° C of the irradiated material (preoxidation); and 3) two-hour heat treatment in vacuum of the preoxidized material at a temperature in the range 400 to 700° C. Specimens prepared for the

EPR study were subjected to an absorbed dose of 2×10^{24} ev/g at a dose rate of 2×10^{19} ev/g·sec or to an absorbed dose of 2×10^{22} ev/g at a dose rate of 10^{16} ev/g·sec. To bring out the effect of oxygen adsorption, in some cases the second step was omitted. It was found that the specimens of irradiated and heat-treated PVA exhibit the same paramagnetic and adsorption properties as the products of irradiation and heat-treatment of polyethylene. It was concluded that the PVA products represent a microheterogeneous system in which predominantly conjugated regions are separated by layers of a less structured material. It was shown that marked oxygen adsorption occurs only on the surface of the conjugated regions, and that in products with an HTT as high as 500, 600, or 700° C, adsorption of one molecule of oxygen causes the reversible disappearance of two paramagnetic centers. In products of low HTT (400° C) oxygen adsorption enhances the metathetical interaction.

As we have seen, the electrical and paramagnetic properties of irradiated and heat-treated PVA are very close to those of similarly treated polyethylene. Yet, the original polymers differ substantially in composition and structure. It was therefore of some interest to study the chemical changes taking place in PVA at various stages of its modification [6]. The procedure involved chromatographic analysis of the evolving products, and elemental analysis and IR spectroscopy of the solid phase at various stages of the process. The main radiolysis products were identified as acet. acid, methane, carbon monoxide, hydrogen, and a small amount of carbon dioxide. Based on the data obtained, a mechanism was postulated for the process of formation of conjugated structures. At a dose of $\sim 1.5 \times 10^{24}$ ev/g, radiolysis of PVA results in the loss of 3×10^{-3} mol/g of acetate groups in the form of acetic acid, and 1.6×10^{-3} mol/g in the form of CH_4 and CO, which are decomposition products of acetate groups. This leads to the conclusion that the process proceeds via two different mechanisms, viz., that the radiation-excited repeat units of PVA can decompose by the reactions:



(1)

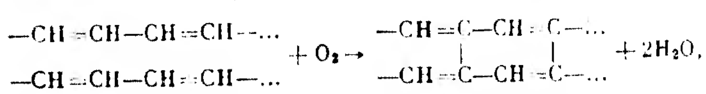


(2)

(the latter reaction is followed by decomposition of the $CH_3COO^{\cdot}$ radical).

The first mechanism gives rise to isolated or, in the case of the loss of acetic acid by adjacent repeat units, conjugated double bonds. In the second mechanism, free radicals are formed which then take part in inter- or intra-molecular crosslinking. The formation of free radicals on radiolysis may also be associated with the evolution of hydrogen, which raises their total number to $\sim 2 \times 10^{-3}$ mol/g or the number of crosslinks to 1×10^{-3} mol/g. This indicates that at a dose of 1.5×10^{24} ev/g, double bonds are formed in one-quarter of all repeat units, and crosslinks, in about one-sixth. It is this substantial crosslinking of PVA that makes possible its subsequent heat treatment without fusion and ignition.

At 250° C in an O_2 atmosphere, the bulk of the CH_3COOH is liberated, which would give rise to linear conjugation if simultaneous liberation of H as H_2O did not produce new crosslinks and cyclization via reactions of the type,



(3)

to form benzene derivatives and two-dimensional conjugated structures of the polynuclear fused hydrocarbon type.

Vacuum pyrolysis at 400—600° C completes the removal of acetate groups and ensures the development of two-dimensional conjugation. At 800° C, the hydrogen content drops sharply and three-dimensional symmetrization sets in.

The results obtained clearly show that conjugation develops in PVA only on the virtually complete loss of acetate groups. Thus, the similarity of the products of irradiation and heat treatment of PVA and polyethylene is governed by their having the same composition and structure. The somewhat better electrical properties in the case of

PVA are attributed to the more highly ordered conjugated structure which is formed upon loss of the substituents regularly alternating in the initial polymer.

With a view toward the study of the conduction mechanism in polymeric semiconductors in general, the mobility of holes excited by an electron pulse in irradiated and heat treated PVA was measured [7]*. It is noted that no direct measurements have so far been carried out of charge carrier mobility for semiconducting conjugated polymers. The measurements were made for film specimens with sprayed gold electrodes. Film thickness (d) was 2—6 μ; electrode area, 0.1 cm^2. Mobility (μ) was determined from measurements of the transfer time (T_t) in the electric field of carriers excited in the layer adjacent to the electrode by single pulses of 1—10 kev electrons lasting 0.2 to 1 μ sec. The results obtained pertain to hole motion. The signal due to electrons is clearly detected in specimens of relatively high conductivity, but it is too weak for quantitative measurement. The measuring circuit constant is greater than T_t. T_t was determined from the time of the rise of the amplitude of the pulse U_v to its maximum value. The dielectric relaxation time exceeded T_t by more than two orders of magnitude. Figure 3 shows oscillograms of pulses at various values of the constant field E for a sample heat treated at 360° C. As Figure 3 indicates, with increasing E, T_t decreases, which indicates the holes reaching the collector electrode. Figure 4 shows electrical data at various temperatures for a specimen with a heat treatment temperature of 360° C. The dependence of $1/T_t$ on the applied field is superlinear (Fig. 4a). Therefore, the effective mobility which is determined from the expression $\mu = d/T_t E$, depends on the magnitude of the electric field which in these experiments was varied from 1×10^4 to 1.5×10^6 v/cm. With increasing ambient temperature, the curves shift toward weaker fields.

Current-voltage characteristics were also recorded (Fig. 4a). In weak fields $< 10^3$ v/cm, the curves exhibit segments in which I is linearly dependent on E. In strong fields, the current increases exponentially with E. In general, the relationship between I and E

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*This work is part of the research cited among the outstanding achievements of Soviet science for 1966 in the annual report [8] of the Main Scientific Secretary of the Academy of Sciences, USSR, published in March 1967.

obeys the equation

$$I = A\exp\left(-\frac{?}{kT}\right)\left[\exp\left(\frac{BE}{kT}\right) - 1\right]$$

In strong fields, as Figure 4a indicates, this relationship is analogous to $1/T_t = f(E)$.

These results make it possible to consider the conduction mechanism. The relationship between conductivity (σ) and temperature and field strength is $\sigma(E,t) = en(E,t)\mu(E,t)$. If carrier concentration (n) does not depend on field and temperature, $\log \sigma(E,t) = \text{const} + \log \mu(E,t)$, and on a log-log scale, values of σ and μ for the same E and t should lie on a single straight line symmetrical to the coordinates. In fact, as Figure 4b indicates, values of σ and μ calculated from independent measurements of I and T_t for three arbitrary values of E at each temperature, lie on a single straight line, and only for the 110° C point do they cease to obey this relationship. Evidently, in this temperature region, thermal liberation of charge carriers begins to have an effect. The hole concentration, which is independent of temperature, is 6.8×10^{13} cm^{-3}. These results indicate that the change of σ with temperature and applied field at sufficiently low temperatures is fully determined by the dependence of hole mobility on these parameters. The activation energy for conduction in the ohmic region is 0.62 ev, and in agreement with the equation given above, decreases linearly with increasing E in strong fields. The activation energy of mobility changes in a similar manner since $\Delta\sigma(t) = \text{const}\ \Delta\mu(t)$.

With increasing ambient temperature, conductivity increases considerably for a given E, and so does mobility. The lowest T_t measured correspond to $\mu = 10^{-3}$ cm^2/V•sec. As the ambient temperature is raised further, conductivity becomes so high that the given determination method for μ becomes inapplicable; however, it may be assumed that conductivity increases further.

The obtained data on the behavior of the effective mobility indicate that it does not represent a microscopic mobility of the regions of uninterrupted conjugation, but evidently includes the transfer of carriers from one region to another. The most probable conduction mechanism for such systems is that proposed by Petritz*. It is the

*Petritz, R. Phys. Rev., 104, 1508, 1956.

over-the-barrier transfer of carriers between conjugated regions which determines the observed behavior of μ and σ.

As most semiconducting polymers studied up to recently are close to each other in electrical properties, it may be assumed that these conclusions apply not only to irradiated and heat-treated PVA but are of more general significance.

The last published paper [9] deals with the effect of additional ionizing radiation on the electrical and paramagnetic properties of the irradiated and heat treated (420—720° C) PVA. Film specimens were irradiated with fast electrons to an absorbed dose of 2×10^{23} ev/g or 10×10^{23} ev/g. It was found that irradiation of the materials causes a change in their paramagnetic and electrical properties. Irradiation with a dose of 10×10^{23} ev/g causes paramagnetic center concentration to drop by a factor of 2 in specimens heat treated at 420 and 520° C and by a factor of about ~ 40 if the HTT was 620° C.

Figure 5 shows the effect of absorbed dose on the conductivity of films obtained at various HTT. As the dose increases to 10×10^{23} ev/g, conductivity does not change within the limits of the experimental error in the case of HTT's equal to 420 to 520° C, but increases by almost one order of magnitude as compared with the original value if the specimens are heat treated at 620° C. The activation energy for conduction does not change with irradiation dose.

It was shown earlier [1, 5] that the structure of irradiation and heat-treatment products of polymers is comprised of conjugated regions of the cyclic type separated by less ordered layers. With increasing HTT the conjugated regions increase, and the layers decrease in size. The layers determine the activation energy. The increasing effect of irradiation with increasing HTT and the nondependence of the activation energy on absorbed dose suggest that radiation mainly affects the conjugated regions and causes an increase in their conductivity.

Additional information on the character of the effect of irradiation on conductivity was obtained by studying the effect of the temperature of annealing of the films after their irradiation. It was found that annealing at above 125° C restores the paramagnetic center concentration prevailing prior to irradiation. This restoration is virtually complete for doses of 2 x 10^{23} ev/g and is partial for doses of 10 x 10^{23} ev/g. In films with HTT of 620° C, the conductivity of samples annealed at above 125° C is also restored to its value prior to irradiation.

Restoration of the electrical and paramagnetic properties by annealing at a relatively low temperature (~125° C) suggests that irradiation does not substantially change the structure of conjugated regions. Therefore, it may be assumed that in films with HTT of 620° C, the irradiation-induced reversible conductivity increase of almost one order of magnitude in the conjugated regions is due to a rise in carrier concentration and not in mobility.

The authors feel that this investigation of the effect of subsequent irradiation on the electrical and paramagnetic properties of irradiated and heat treated PVA has contributed to a greater understanding of the nature of paramagnetic centers in irradiated and heat-treated polymers. In fact, their earlier [10] postulate that paramagnetic centers are not the source of charge carriers, i.e., not charge transfer complexes, is confirmed by the fact that a drop in paramagnetic center concentration on irradiation is accompanied not by a decrease but by an increase in the conductivity of the conjugated regions.

Figure 6 shows an energy scheme of conjugated regions between layers. Irradiated and heat-treated PVA products are p-type semiconductors. This means that in them, charge carrier concentration is directly determined by the number of fully ionized acceptor centers (Figure 6, level A). It may be postulated that the paramagnetic centers are not defects of the acceptor type, since if they were, any change in the concentration of these paramagnetic centers as a result of an external factor would cause an equivalent change in carrier concentration. Earlier, it was postulated [10] that the paramagnetic centers are structural defects of the type of trivalent carbon atoms. Evidently these defects behave as traps for the electrons which in this case may be generated by irradiation. The probable scheme of the processes taking place is shown in Figure 6. Irradiation generates electron-hole pairs. Simultaneously, with the subsequent recombination of electrons with holes, electrons are trapped by the existing paramagnetic centers. The observed drop in the paramagnetic center concentration is the result of the "pairing" of the spins of the trap and of the electron. The simultaneous appearance of excess holes determines the increase in the conductivity of the films. Annealing at temperatures above 125° C causes the ejection of electrons from the traps. These electrons recombine with holes, resulting in the restoration of the electrical and paramagnetic properties of the samples prior to irradiation.

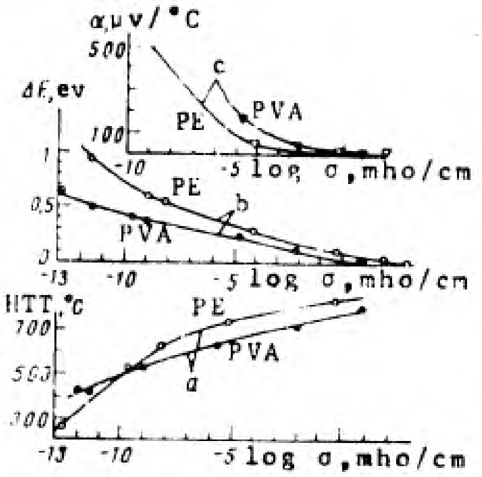

Fig. 1. Electrical properties of semiconducting polymers from poly(vinyl acetate) (PVA) and polyethylene (PE) compared

a - Heat treatment temperatures (HTT); b - activation energies; c - thermoelectric power as a function of conductivity at 20°C.

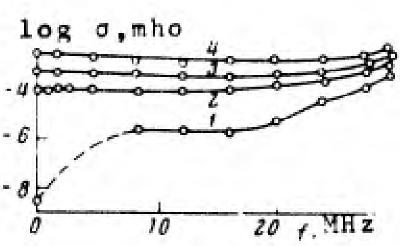

Fig. 2. Frequency dependence of electrical conductivity of irradiated and heat-treated poly(vinyl acetate). Heat-treatment temperature: 1) 620; 2) 720; 3) 820; 4) 910°C

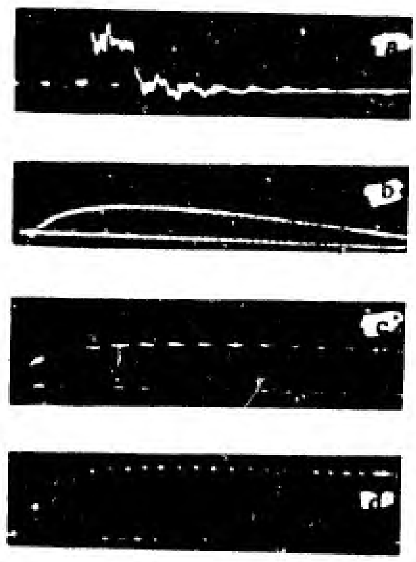

Fig. 3. T_t versus E

a - Exciting electronpulse (distance between divisions, ℓ = 0.2 μsec); E (v/cm), ℓ (μsec), and T_t (μsec), respectively: b - 3.3 x 10^5, 25, and 300; c - 3.8 x 10^5, 25, and 100; d - 5 x 10^5, 5, and 30; film thickness, 2.5 μ.

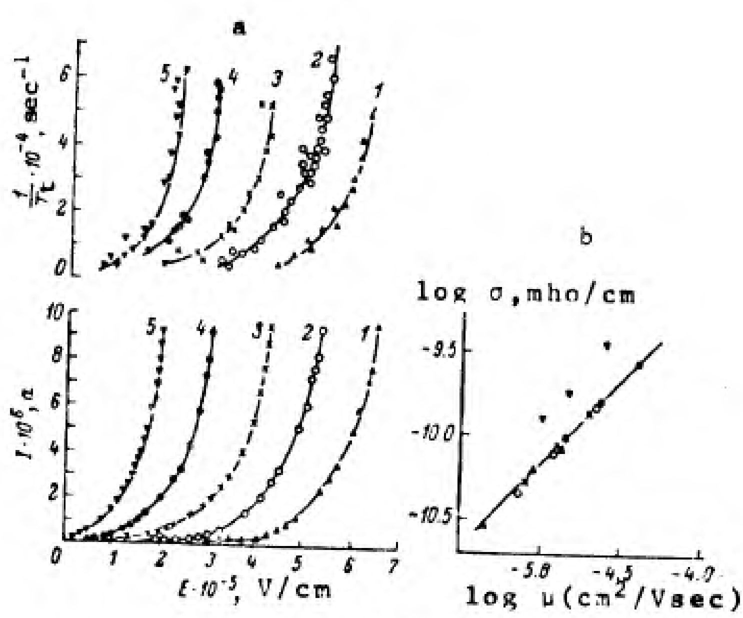

Fig. 4

a - $1/T_t$ and I versus E (t, °C: 1) 11, 2) 18, 3) 40, 4) 72, 5) 110); b - σ versus μ.

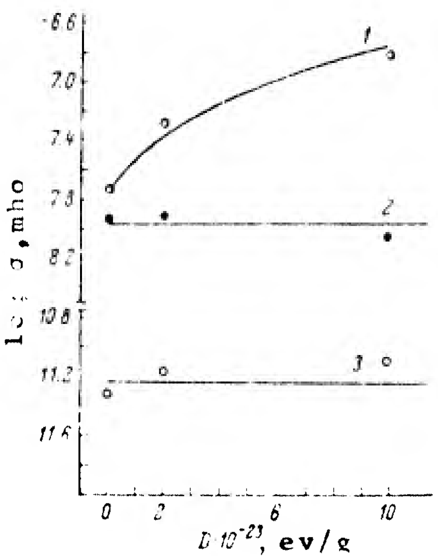

Fig. 5. Electrical conductivity (σ) versus absorbed dose

HTT, °C: 1) 620; 2) 520; 3) 420.

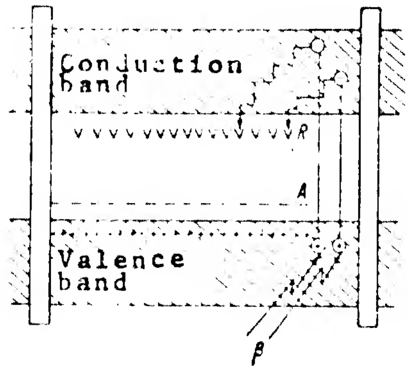

Fig. 6. Postulated scheme of processes occurring in organic semiconductors based on poly-(vinyl acetate) on irradiation

Table 1

Material	HTT, °C	$\sigma_{20°}$, mho/cm	σ_0, mho/cm	ΔE, ev	α, μv/°C
Initial PVA	—	$1\cdot10^{-18}$	—	—	—
$D=5.6\cdot10^{23}$ ev/g	—	$2\cdot10^{-14}$	—	—	—
$D=5.6\cdot10^{23}$ ev/g	420	$3.3\cdot10^{-12}$	$1.1\cdot10^{-3}$	0.50	—
$D=5.6\cdot10^{23}$ ev/g	520	$1\cdot10^{-9}$	$2.8\cdot10^{-3}$	0.38	—
$D=5.6\cdot10^{23}$ ev/g	620	$2.3\cdot10^{-4}$	$2.9\cdot10^{-1}$	0.24	+160
$D=5.6\cdot10^{23}$ ev/g	700	$1.0\cdot10^{-5}$	$5.1\cdot10^{-1}$	0.10	+32
$D=5.6\cdot10^{23}$ ev/g	800	$10\cdot10^{-2}$	100	0.05	+1.5

Table 2

D, ev/g	$2\cdot10^{20}$	$5{,}6\cdot10^{[illegible]}$	$3\cdot10^{[illegible]}$
ΔE, ev σ_{20°, mho/cm	0,32 $2{,}9\cdot10^{-8}$	0,24 $2{,}3\cdot10^{-5}$	0,14 $2\cdot10^{-4}$

Table 3

HTT, °C	520	620	720	820	910
σ_{20°, mho/cm ΔE, ev	$1\cdot10^{-10}$ 0,33	$3\cdot10^{-7}$ 0,24	$5\cdot10^{-2}$ 0,10	1,0 0,08	10 0,07

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SOLAR X-RAY EMISSION SIGNALS ASTRONAUT RADIATION DANGER

by D. Michaels

SUMMARY: Recent investigations indicate that the monitoring of solar x-ray emissions may aid in the establishment of a reliable flare warning system to ensure astronaut safety. Reportedly Kosmos-166 has confirmed earlier findings by Elektron-2 on the occurrence of x-ray bursts in connection with dangerous corpuscular flares. A survey of recent Soviet reports indicates Kosmos-166 represents a significant technological advance towards, if not the achievement of, a flare warning system based on the monitoring of solar x-radiation.

On 2 October 1967 it was reported [1] that Kosmos-166 and Elektron-2 had "in principle" demonstrated that the monitoring of solar x-ray flares can provide the basis of a reliable method of forecasting dangerous radiation conditions in space. The article stated: "In principle, by recording an x-ray flare, it is possible to warn astronauts of the approach of radiation danger, thus enabling spaceship crews to take the necessary protective measures." This press release culminates a series of reports indicative of continuing Soviet interest in solar x-radiation as the basis of a flare prediction system, an approach to flare prediction also pursued by U.S. investigators.

Review of Past Soviet Investigations of Solar X-Radiation

Rocket investigations of solar x-radiation were initiated in the USSR [2] by A. V. Yakovleva of the State Optical Institute and S. L. Mandel'shtam of the P. N. Lebedev Physics Institute in the late forties, or shortly after similar investigations were undertaken in the United States with captured V-2 rockets. On 21 July 1959 a geophysical rocket, measuring solar radiation in the 2—10-Å range, recorded a radiation flux of 7×10^{-4} erg/cm$^2 \cdot$ sec at a height of 92 km. In an attempt to locate the region of the corona in which the x-rays are generated, a geophysical rocket, again recording in the 2—10-Å range, was launched during the total solar eclipse of 15 February 1961 and recorded a flux of 8×10^{-5} erg/cm$^2 \cdot$ sec at a height of 96 km. At the time of measurement, the entire Sun was occulted, with the exception of two active regions on the western and eastern limbs. In more recent geophysical rocket experiments, Soviet scientists have succeeded in obtaining valuable x-ray photographs of the Sun at heights of 500 km. A new type of stabilization system made it possible to point the camera directly at the Sun for periods of several minutes. Details having a magnitude of one-thirtieth of the diameter of the Sun can be identified on these photographs. In the opinion of Soviet scientists, close analysis of x-ray burst photographs of this type should provide a forewarning of solar radiation danger for manned space flights.

The use of longer-lived satellites of the Kosmos and Elektron series made possible long-range comparisons with the solar activity cycle. For example, Elektron-2, measuring in the 2—10- and 8 to 18-Å range, in the period from 30 January through 16 March 1964, showed the average solar x-radiation level to be much less than it was in 1959—1960, the period of solar activity maximum. In the course of the 11-year cycle, solar x-radiation changed by an order of magnitude. Thus, in the wavelength region shorter than 10 Å, the flux varied from 1×10^{-5} to $(2—3)\ 10^{-3}$ $erg/cm^2 \cdot sec$; in the 10—20-A range, it varied from 1×10^{-4} to $(1—2)\ 10^{-2}$ erg/cm^2 sec; while in the 40—60-A range, the flux varied from 1×10^{-2} to 5×10^{-2} $erg/cm^2 \cdot sec$. The total solar x-radiation flux (to 100 Å) was 0.1—1 $erg/cm^2 \cdot sec$.

Comparison of solar x-ray photos with Sun charts in the radio range has shown that the region of increased x-ray emission coincides with that of radio emission at 10—20 cm. Experimental data have also confirmed the thermal nature of solar x-radiation. Like radiowave emission, x-ray emission is also built up of an "almost constant" and a "slowly changing" component. The former refers to the undisturbed corona, the latter to the hotter radiation of active coronal regions. The emission from the slowly changing component depends greatly on the quantity and parameters of the active regions. Using data obtained by ground radio-astronomical stations operating at 10.7 cm, it is possible to forecast solar x-ray emission during periods of minimum solar activity.

In periods of maximum solar activity, however, the problem is much more complex. Currently, the Crimean Astrophysical Observatory under the direction of A. B. Severnyy is studying the relationship between solar x-ray bursts and the occurrence of solar flares that create dangerous radiation conditions in space. It is hoped that a systematic study of x-ray flares together with other solar-activity phenomena will eventually explain the mechanism of solar flares and thereby lay the foundation of a reliable flare prediction system.

Analogous experiments are being conducted by U.S. investigators. The University of Michigan under the direction of R. Teske of the McMath Hulbert Observatory has for some time been studying the relationship between solar x-rays and flares on the basis of OSO-3 data. Distinct correlations have been found between x-ray records, the intensity at two points in a solar flare, and shortwave radio fading at 10 MHz [3].

Orbital Elements of Elektron-2 and Kosmos-166

The report in *Pravda* on 2 October 1967 stated that Kosmos-166 had confirmed the earlier findings of Elektron-2 with regard to solar x-radiation. The orbital elements of these vehicles are given in Fig. 1. [The article in *Pravda* incorrectly gives the launch date of Kosmos-166 as 16 July instead of 16 June.]

Vehicle	Launch date	Perigee (km)	Apogee (km)	Period (min)	Inclination
Elektron-1	30 Jan 64	406	7100	2 hr and 49 min	61°
Elektron-2	30 Jan 64	460	68,200	22 hr and 40 min	61°
Kosmos-166	16 Jun 67	283	578	92.9 min	48°4'

Fig. 1. Orbital elements of Elektron-2 [4] and Kosmos-166 [5]

The orbital line of apsides of Elektron-2 was selected in order to intersect as large a range of the outer radiation belt as possible over the same geographic latitude, while reducing Moon- and Sun-induced orbital perturbations to a minimum. Kosmos-166, whose orbital elements [Fig. 1] closely resembled those of Kosmos-163, launched 10 days earlier, followed the well traveled path of Kosmos-8, -14, -19, -23, -31, -49, -51, -76, -93, -95, -101, -106, -116, and -123. In addition, solar x-radiation measurements are known to have been made by Kosmos satellites having an inclination of 65°. It is clear, therefore, that Kosmos-166 represented a more technologically advanced craft than its predecessors. This is spelt out in detail in the *Pravda* article of 2 October 1967.

Following is a partial translation of the article on Kosmos-166 which appeared in *Pravda* on 2 October 1967.

Kosmos-166

"Kosmos-166 is a modification of the serial space vehicle having one axis of the satellite oriented toward the Sun. Control of the motion of the body of the satellite in flight is accomplished by inertial masses--flywheels and gas jet engines.... Three times during each orbit, on command from a programmed timing device, the orientation system goes into the so-called scanning regime, in which the axis of the satellite intersects the solar disk in one direction with an angular velocity of 0.04° per second... memory units store data for retransmission when communication with the ground stations is impossible... the systems are powered by solar batteries.... The scientific apparatus on Kosmos-166 consists of an x-ray photometer, a diffraction ultraviolet spectrometer, and an x-ray heliograph. Geiger counters with an oxygen quenching admixture and beryllium or aluminum windows serve as radiation receivers for the x-ray photometer. The investigations were conducted in those parts of the spectrum which are especially interesting for solar flare studies. A control counter was used to evaluate the level of interference from particles in the radiation belts. The x-ray heliograph consists of two similar sensor blocks located outside the satellite and an electronics block inside the satellite. Each sensor block has x-ray Geiger counters with fields of view determined by two crossed slit diaphragms. When the satellite axis intersects the solar disk, its image is obtained along two mutually perpendicular directions. Optical sensors, accurately fixing the moments of solar limb passage through the field of view of the counters, are used to relate the records obtained of specific sectors on the Sun. A concave diffraction grating is the main component of the spectrometer. The instrument records the radiation with the aid of an open photoelectric multiplier.... Simultaneous spectrometric recordings of the line of ionized helium yield valuable information on the state of the solar ionosphere above the flare." [6]

Data Obtained

The article also noted that since Kosmos-166 has been in operation for about three months, or three solar revolutions, during which time solar activity has varied greatly, much useful statistical data on the relationship between optical and x-ray flares have been obtained. Although the data were considered preliminary, the following conclusions were reached.

"Thus, the time of build-up for most flares ranges from 0.5 to 20 minutes. The intensity fade-off is not always monotonic. In one instance, a "harbinger"--a small burst preceding the main flare--phase was observed. Some indirect data (ionospheric measurements) can also indicate the existence of such "harbingers." The simultaneous analysis of the spectral radiation composition shows that there are relatively "cold" and "hot" flares. Often, a temperature decrease is noticed during the process of development. As a rule, x-ray flares occur above active regions that can be observed optically from the ground. Usually the size of the flare region does not exceed three angular minutes. It is especially interesting that in four cases the presence of two centers of about equal brightness intensity was observed in a single flare. The distance between them was about six angular minutes.

These results also confirm earlier findings, especially those made by Elektron-2. At that time, the presence of a special class of x-ray flares which are not accompanied by optical flares was established. These observations indicate a localization of part of the x-ray flares in the corona. The coronal origin of x-ray flares suggests that they are closely connected with perturbations in the corona that lead to corpuscular flares which are dangerous for space flights." [7]

However, the authors of this article are careful to qualify the conclusion that a final solution to the flare prediction problem has been found. This qualification, which was omitted in abbreviated reviews of the article, follows.

"The corpuscular streams propagate more slowly than the x-radiation because of the lower particle velocity and longer flight trajectory. Therefore, in principle, by recording x-ray flares, it is possible to warn astronauts of approaching radiation danger--corpuscular streams. This warning will give the spaceship crew time to take the necessary protective measures.

Of course, the development of such a short-range radiation-danger warning system does not exclude the necessity of creating methods of predicting corpuscular flares. On the contrary, the complex solar investigations necessary for this must be significantly expanded. The special urgency of such investigations is highlighted by the fact that in the coming years manned space flights will be conducted on an ever wider scale, and a period of increased solar activity is approaching when instances of radiation danger will be very frequent." [8]

Other Flare Investigations

Indeed, new laboratory and theoretical investigations are announced constantly and are indicative that the radiation problem confronting astronauts is far from solved. Cited below are several examples of such research, which were reported the same time as the *Pravda* solar x-ray flare article.

Komsomol'skaya Pravda [9] reported the development of a new installation, called the "biological block," consisting of a chamber divided into sections into which animals are placed to test the impact of solar flare radiation. Their behavior is observed by television. The radiation is generated by a gamma cobalt installation producing an overall radiation dosage of 900 roentgens. The experiments established that special pharmacochemical substances had the same effect on white mice during simulated "solar flares" as during ordinary irradiation.

The second announcement was that V. Chistyakov, working at the Ussuri Solar Observatory, had established [10] that the bright formations (5000—10,000 km in diameter; lifetime about 2 days) which appear inside or near sunspots move along vortical trajectories, confirming the hypothesis that solar spot matter and the magnetic fields associated with it are constantly rising up from the solar mass.

On 8 October 1967 the director of the Pulkovo Observatory, Prof. V. A. Krat, announced [11] that a second balloon-lofted astronomical observatory, carrying a large telescope, spectrograph, photographic and TV equipment, had been launched into the stratosphere to conduct solar investigations. A large number of photographs and spectrograms of the surface of the Sun have already been received from the automatic station. The stratospheric station may be used again for future experiments after retrieval. The first such balloon observatory weighing 7.6 tons ascended to a height of 20 km on 1 Nov 1966. [12]

On 12 October 1967 another noteworthy space probe, intended to study the upper layers of the atmosphere, the ionosphere, and near space, was launched to a height of 4400 km. The main purpose of this probe reportedly [13] was to obtain data on the electron and positive ion concentration, electron temperature, cosmic ray intensity, radiation conditions, and the density of neutral hydrogen. After the apparatus was launched into the planned trajectory, the rocket carrier was successfully moved a greater distance away so that the ejected gases would not obstruct the studies underway.

Polish investigators have reported [14] that the second largest hodoscope in Europe had been built under the direction of W. Stefanski for the study of cosmic rays. The fully-transistorized instrument is operated by the Institute for Nuclear Research in Lodz.

Conclusion

It must be concluded, therefore, that the construction and findings of Kosmos-166 represent a noteworthy advance in the development of a reliable flare prediction system, but not the attainment of it. [DM]

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6. Mandel'shtam, S., V. Mikhaylov, and Yu. Zaytsev. Kosmos-166 in the solar patrol. Pravda, 2 October 1967, 3, cols. 2-8.

7. Idem.

8. Idem.

9. Komsomol'skaya Pravda, no. 224, 23 September 1967, 4, cols. 1-3.

10. FBIS (USSR East Europe), 9 October 1967, cc 9.

11. Komsomol'skaya Pravda (Litva), 8 October 1967, p. 1, cols. 5-6.

12. Leningradskaya Pravda, 10 November 1966, p. 4, cols. 5-6.

13. FBIS (USSR East Europe), 13 October 1967, cc 10.

14. Neues Deutschland, 20 August 1967, p. 11, cols. 3-7.

NOTES

EXPERIMENTAL OPERATION OF A GAS MASER ABOARD AN ARTIFICIAL EARTH SATELLITE

A maser oscillator (Fig. 1), used as a frequency standard aboard a satellite, is discussed. The oscillator's frequency stability was measured by means of a system of two-way radio communication with the satellite.

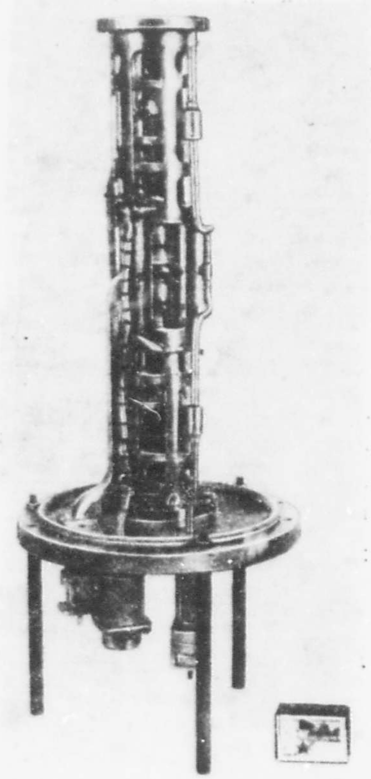

Fig. 1. Satellite-borne maser oscillator

The oscillator, which operated on two opposing beams of ammonia $N^{14}H_3$ molecules, generated oscillations with a frequency of 23,870 MHz on an inversion spectral line with quantum numbers J = 3, K = 3. The oscillator's 10-cm-long resonance cavity was made of superinvar and the temperature was thermostatically controlled with an accuracy of better than 0.01° C. Sorting of ammonia molecules, with respect to energy levels, was done by six-pole electrostatic capacitors consisting of radially arranged plates between which a stabilized voltage of 7500 v was applied. The molecular beam source, which had the shape of a cylinder 3 mm in diameter and 3 mm long, consisted of approximately 3000 thin channels parallel to the axis of the cylinder.

The ammonia consumption during continuous operation of the oscillator was 0.5—0.75 g daily. This amount was supplied through a porous ceramic orifice which insured the required molecular beam intensity. Liquid ammonia reserves, permitting continuous operation of the oscillator for four months, were placed in a titanium container under a pressure of ~20 atm (Fig. 2). The lowering of pressure, up

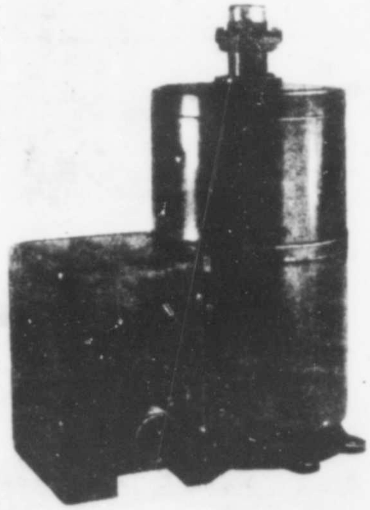

Fig. 2. Liquid ammonia container with thermostat, orifice, and remotely controlled valve

to ~1 mm Hg, was accomplished by means of the same ceramic orifice. The oscillator weighed 2.2 kg; the ammonia container, together with the orifice and the thermostat, weighed about 2.5 kg.

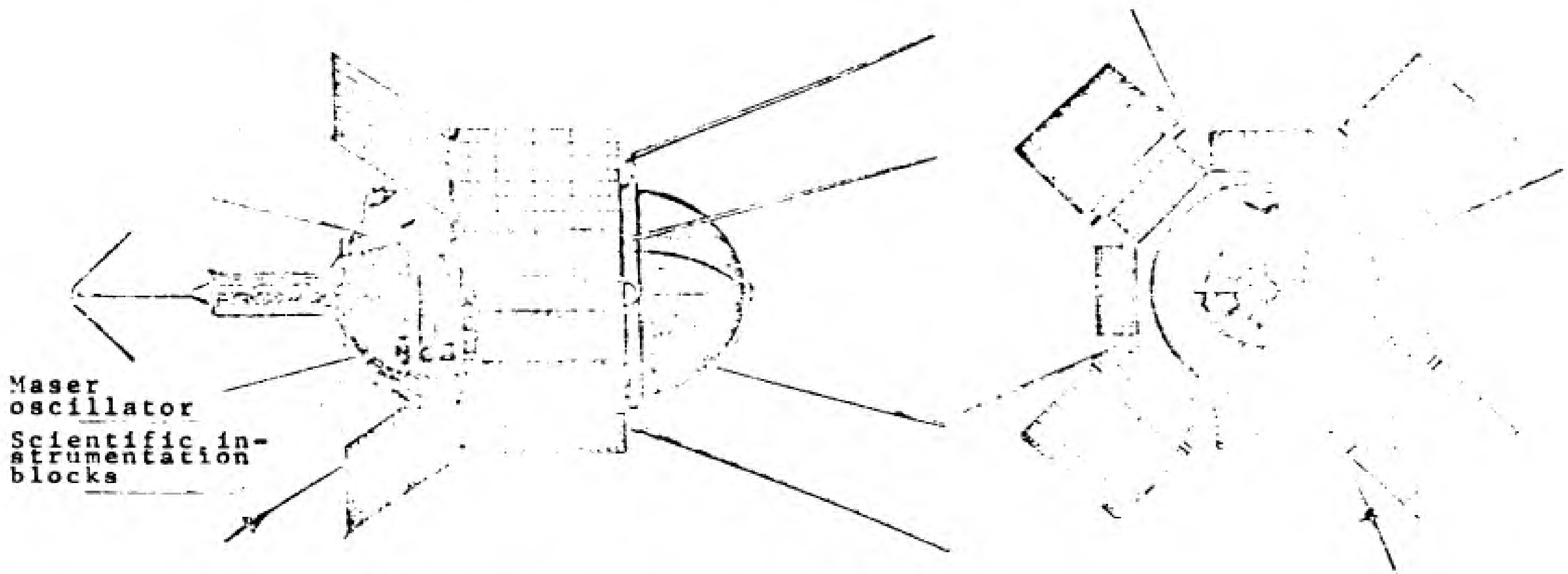

Fig. 3. General view of artificial earth satellite with maser oscillator

The oscillator was mounted on the exterior surface of the satellite beneath a hood with dual walls which contained ports for discharging ammonia into outer space (Fig. 3). The hood also served as a base upon which the receiving and transmitting antennas were mounted.

Through hermetically sealed leads, the oscillator was connected with the instrumentation inside the satellite, where normal temperature and near-atmospheric pressure of an inert gas were maintained. The energy of the oscillations generated was tapped by means of a waveguide equipped with a ferrite isolator to prevent a load effect on the operation of the oscillator. The frequency of the quartz oscillator (about 25 MHz) used in two-way radio communications with the ground-based station was stabilized by the maser oscillator frequency through automatic phase tuning.

Three identical independent maser oscillators which differed from the oscillator on board the satellite only in the ammonia vacuum pumping system were installed at the ground-based station. Frequency variations in any of the three oscillators could then be determined exactly with respect to the other two.

Two-way radio communications with the satellite were maintained in the decimeter band, where the effect of the ionosphere on fluctuations in the signal frequency is small.

The operation of the maser oscillator under actual space flight conditions was tested on the Kosmos-47 satellite. Analysis of both the telemetered and frequency-measurement data led to the following conclusions: 1) The maser oscillator operated normally at various satellite altitudes within and outside the Earth's radiation belt, both in sunlight and in the Earth's shadow. The relativistic frequency stability in a single measurement had a value of $\sim 10^{-11}$. 2) A system of two-way radio communications with the satellite insured frequency measurements with an accuracy of 10^{-11}. The frequency drift, caused by the nonrelativistic Doppler effect, was cancelled up to 10^{-5} of its value. The uncancelled part of the frequency variation, due to the effect of the ionosphere, was within the limits of permissible measurement errors. 3) The possibility of synchronizing the frequencies of the space borne and the ground-based maser oscillators by means of two-way radio communications and automatic phase tuning was thus confirmed. [JR]

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AUTOMATIC DIAGNOSIS OF HUMAN ORGANISMS

The author presents two variants of a system used in the automatic diagnosis and monitoring of functions in human organisms. Automatic diagnosis is based on the measurement and analysis of physiological parameters.

In the first stage of automatic diagnosis, signals are collected from sensors such as simple electrodes for recording electroencephalograms, electromyograms, electrocardiograms, and galvanic skin reactions; potentiometric sensors for recording the rate and depth of respiration; piezoelectric sensors for recording pressures; level gages for measuring blood pressures; and strain gages for measuring physical effort. Signals from these sensors are amplified either by a-c amplifiers with gains of the order of 10^7, with a high rejection of the 50-Hz power line frequency, or by d-c amplifiers with gains of the order of 2×10^3.

Since signals from various sensors differ, diverse methods are used for their processing. Thus, in the second stage of diagnosis, i.e., in the analysis of low-frequency electroencephalogram and electromyogram signals, a common differential amplifier with n parallel branches having narrow-band RC filters is used. Signals are thus separated according to frequencies after which they are integrated separately as well as collectively. Signals are also analyzed on the basis of the frequency with which they cross the zero axis (i.e., instantaneous frequency). These signals are pulse coded and linearly transformed to analog form, and then processed as previously. Sometimes amplitude spectral analysis is also applied, in which case the histograms display the statistical parameters of the observed random process.

The last stage of automatic diagnosis is related to quantitative evaluation of physiological parameters according to a specified algorithm. The two automatic diagnostic systems described by the author differ in this respect. In the first system (see Fig. 1), which is intended for diagnosis of human organisms whose normal states are known from previous studies (e.g., pilots or astronauts), the measured signals are identically coded and compared to reference levels which correspond to physiological parameters of the same subject measured when conditions of stress were absent. The results of comparing signals $Y_1^j, Y_2^j, \dots, Y_n^j$ to the allowable range of their variations are coded into logical levels. A logic equation using these levels as variables defines any one of ℓ organism states such as state $S^j \rightarrow Y_1^j \vee Y_2^j, \dots, \vee Y_n^j$. The latter operation is easily realizable by means of logic matrices. The system of Fig. 1 is used for diagnosing

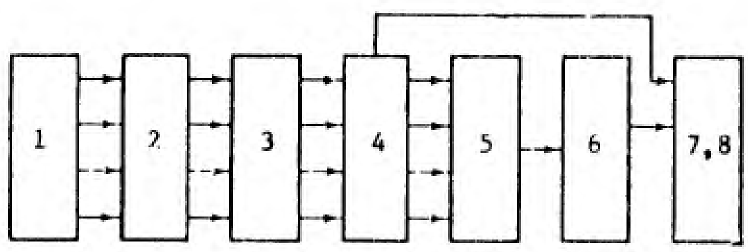

Fig. 1. Automatic diagnostic machine (variant no. 1)

1 - Physiological parameter sensors; 2 - amplification unit; 3 - analyzer unit; 4 - converters; 5 - threshold element and logical unit; 6 - logical block; 7,8 - display and output units.

three stages of acute hypoxia: 1) consistently adaptable, 2) partially noncompensated oxygen starvation (causing disorders in the central nervous system), and 3) completely uncompensated oxygen starvation. Five parameters are used to define these states: electroencephalogram, electrocardiogram, O_2 content in the blood stream, blood pressure, and respiration rate.

The above system is, however, limited in the sense that when the symptom groups of the subject being tested are not previously known, errors may be introduced due to individual differences between several organisms. The second version of an automatic diagnostic system (see Fig. 2) takes this fact into account, incorporating it into a different algorithm in which the organism's state is estimated on the basis of physiological parameters which are individually weighed according to their rate of change and the effect of this change on a particular organism. The machine, while primarily intended for monitoring the state of a subject undergoing surgery, may also be used in other medical and biological applications where up to 9 parameters and their interrelationship are to be monitored. The average value of individual parameters is dynamically stored in the machine memory for a predetermined amount of time. After this period elapses, the average values are calculated again by means of integrators as in the first variant. In this machine, the logic matrix defining the organism states K_i uses cold cathode tubes, which display variations of each physiological parameter between preset limits.

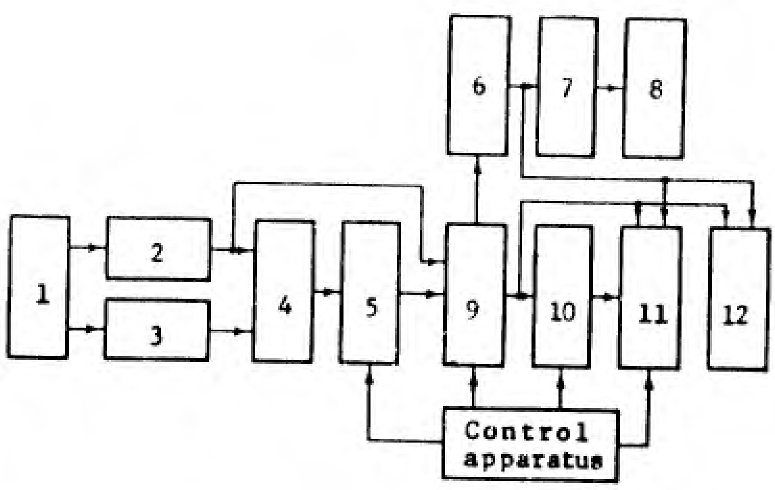

Fig. 2. Automatic diagnostic machine (variant no. 2)

1 - Sensor; 2 - d-c amplifier; 3 - a-c amplifier; 4 - analyzer; 5 - integrators; 6 - block defining percent parameter deviation; 7 - adder; 8 - indicator unit; 9 - memory; 10 - threshold elements; 11 - visual memory; 12 - two-track recorder.

Thus, for example, an anesthetist associates each organism's state with a particular visual picture. Also, exact data is recorded by means of a two-track recorder for post-surgical analysis.

The algorithm in this variant is flexible enough to permit physiological parameters to have different degrees of importance. An extension of this algorithm may be incorporated (requiring the aid of a digital computer), which could not only control the "current" state of the organism but also prevent the onset of certain dangerous states in a human, with a predetermined degree of probability. [BD]

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ECHO-2 ULTRASONIC ENCEPHALOGRAPH

The Echo-2 ultrasonic encephalograph, which was exhibited at Expo-67, was developed by a team from the Medical Equipment Research Institute of the USSR. The apparatus will make it possible to diagnose brain diseases ultrasonically. The operation of the device is based on the different modes of reflection of ultrasound from the interface of tissue layers having different thicknesses. Echo-2 was designed for diagnosis of major blockages of blood circulation in the brain, damage to the central nervous system, and brain inflammation conditions. Diagnosis is said to be simple. No special preparation of the patient is necessary and the device is "completely safe." Echo-2 generates ultrasonic waves of frequencies between 1 and 2.5 megacycles. [SK]

REFERENCE

Echo-2, a new type of electronic diagnosing apparatus at the World's Fair. Die technik, v. 22, no. 9, 1967, 596-597.

USING THE NMR METHOD TO STUDY THE INCORPORATION OF PLASTICIZERS INTO POLYMERS

The process of incorporating plasticizers into poly(vinyl chloride) (PVC) in the course of mixing and milling has been studied by the NMR method. This method, developed by the authors [1, 2], is based on the determination of plasticizer molecule mobility in the polymer from changes of the spin-spin relaxation time (T_2).

In the case of mixing, technical-grade PVC (PVC-70) and 10 to 60% plasticizers such as dibutyl phthalate (DBP), dioctyl phthalate (DOP), or dioctyl sebacate (DOS) were used which are compatible with

PVC, or castor oil, which is incompatible with PVC. The plasticizer incorporation was performed in two steps: mixing of the plasticizer-PVC charge in a Werner mixer for 20 min at room temperature, and then for up to 60 min in the same mixer preheated to 98°C.

The dependence of T_2 on the mixing time is given in Fig. 1. The minimum mixing times (t^m min) for various plasticizer concentra-

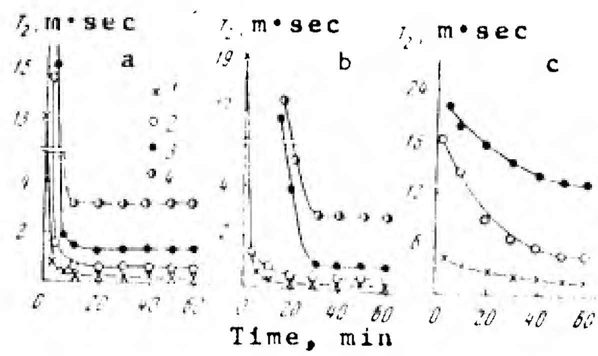

Fig. 1. Dependence of spin-spin relaxation T_2 on the mixing time at 98°C for the systems

a - PVC-DBP; b - PVC-DOP; c - PVC-DOS; 1 - 30; 2 - 40; 3 - 50; 4 - 60% plasticizer.

tions were found to be:

Table 1

Plasticizer, %	30	40	50	60
t^m, min for DBP	1.5	4	4.5	5
t^m, min for DOP	1.5	4.5	27	28
t^m, min for DOS	27	30	38	—

It is noted that t^m decreases with an increase in polymer-plasticizer compatibility. Analysis of the result indicated that in the case of PVC and a compatible plasticizer the molecular interaction is strong, and mainly intrasheaf plasticization takes place. In the case of an incompatible polymer-plasticizer mixture (PVC + 10% castor oil), T_2 remained unchanged on mixing at 93°C for 60 min. In this case the PVC-plasticizer molecular interaction was weak, and plasticization was mainly intersheaf.

The dependence of T_2 on the milling time of films given in Fig. 2 shows that T_2 drops with increasing temperature and milling time. An increase of these parameters favors penetration of the

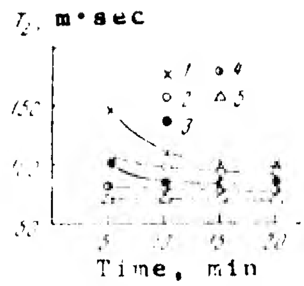

Fig. 2. Dependence of spin-spin relaxation T_2 on the mixing time

1 - 120°C; 2 - 130°C; 3 - 140°C; 4 - 150°C; 5 - 160°C.

plasticizer in the morphological forms of the polymer to form more homogeneous polymer-plasticizer systems.

The results of the study are as follows: 1) it was confirmed that the NMR method is suitable for studying the incorporation of plasticizers into polymers; 2) the possibility was shown of determining the minimum mixing times of PVC with some plasticizers; and 3) it was confirmed that in the case of compatible plasticizers plasticization is mainly intrasheaf, while in the case of incompatible plasticizers it is mainly intersheaf. [BO]

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LASER SIMULATION OF NUCLEAR EXPLOSIONS

A laser-induced spark in air can be regarded as a model of a nuclear explosion. Research along this line has been carried out at the Physics Institute im. P. N. Lebedev in Moscow. A magnetic field was used to investigate the plasma bunch resulting from the laser-induced spark. The researchers discovered that the magnetic field perturbation and light emission were recorded long after the original laser pulse had gone. They further established that the abnormally long plasma lifetime was due to the spatial expansion of the plasma bunch. A halo surrounded the spark that was preceded by a long-lifetime ionization front generated by the shock wave. It was suggested that these phenomena are similar to ball lightning. The scientists then applied the known formulas defining the lifetime of the fireball of a nuclear explosion to the laser-induced spark and found complete agreement with the experimental results. The laser-induced spark experiments are expected to furnish a wide range of possibilities for scientific and technical application. [SK]

REFERENCE

Laser simulation of nuclear explosions. Die technik, v. 22, no. 9, 1967, 596-597.

MULTICHANNEL RECEIVER FOR SPACE SIGNALS

According to Nikolay Kardashev, the USSR has developed equipment to receive signals from possible extraterrestrial civilizations. Dr. Kardashev, Deputy Chairman of a section entitled "Search for Signals of Extraterrestrial Civilizations" which is attached to the Council of the USSR Academy of Sciences, described the equipment (a multichannel receiver) at a General Session of Soviet Physicists. Kardashev revealed that a search effort will be made this year in an attempt to collect information from distant objects in space, and that particular attention will be focused on wavelengths under 10 cm. Kardashev stated that receivers now exist for all wavelength ranges. Within 10 years, Kardashev feels, man will understand more about the information being transmitted by cosmic radiation sources. The infrared range, about which relatively little is known today, will be especially important, and quasars will be a prime object of study.

[SK]

REFERENCE

Signals from the universe. Die technik, v. 22, no. 9, 1967, 597.

BOOK REVIEWS

ELECTRICAL MEDICAL APPARATUS

Liventsev, N. M. Elektromeditsinskaya apparatura; printsip deystviya, ustroystvo, ekspulatatsiya (Electrical medical apparatus; principles of operation, installation, and use). 3d ed., rev. and enl. Moskva, Izd-vo "Meditsina," 1964. 344 p.

This book describes in great detail a wide variety of electrical medical equipment used for therapeutic and diagnostic purposes in the Soviet Union. Each chapter treats a specific class of equipment; the first part of the chapter is devoted to general considerations and succeeding sections cover individual devices. The developmental history of the devices is given, including such information as previous models, where developed and manufactured, etc. The extremely detailed descriptions of apparatus are often supplemented by photographs, pictures, block and schematic diagrams, circuit diagrams, and specifications. This book should be an extremely valuable reference tool for those whose work impinges upon this field. This book has not been translated; however, NASA recently requested a complete translation. The following table of contents is complete and provides an accurate summary of the contents of the book.

TABLE OF CONTENTS:

[EL]

AEROPHYSICAL INVESTIGATIONS OF SUPERSONIC FLOWS

Aerofizicheskiye issledovaniya sverkhzvukovykh techeniy (Aerophysical investigations of supersonic flows). Moskva. Leningrad, Izd-vo Nauka, 1967. 304 p.

From this collection of 34 articles can be seen the recent trends and achievements in theoretical and experimental research being conducted in the laboratory for the study of aerophysical problems of supersonic aerodynamics of the Physicotechnical Institute im. A. F. Ioffe, AS USSR, established in 1953. In spite of their general interest, a review of each article is not within the scope of this review. The articles are grouped into two parts, Part I of which contains 11 items dealing with experimental investigations of various phenomena associated with shock waves produced in shock tubes, articles describing various methods, equipment, and tools for measuring the state and parameters of gases behind a shock wave, and an article dealing with MHD effects in shock-tube flows.

Two articles are particularly noteworthy. The first, a detailed analysis of a simple shadow method for investigating shock wave -- body interaction in shock tubes, is based on a large amount of experimental work using the direct method of silhouetting the inhomogeneities of a medium by means of a light beam without any intermediate optics. The second is an interferometric investigation of the state of xenon and mercury vapors in a shock tube in the Mach range of an incident shock wave (M = 7—16 for xenon and M = 7—14 for mercury vapors). The Rozhdestvenskiy method was used to determine the distribution of normal ($6s\,^1S_0$) and excited ($6p\,^3P_{0,1,2}$) atoms of mercury in front of and behind a shock wave. A review of special problems connected with the interferometric method, followed by a detailed description of the experimental arrangement, is included.

The basic trends of theoretical research are presented in Part II, in which the effect of variable properties of gases behind a shock wave on flows around blunted bodies is considered. It is shown that the effect of variable heat capacity substantially affects the location and shape of a shock wave, and that the dependence of the shock standoff distance along the symmetry axis is a non-monotone function of the Mach number. The investigation of simultaneous vibrational and dissociating relaxation shows that the sonic line has its curvature oriented toward the body.

Besides this theoretical trend, an article dealing with the application of the asymptotic method to the integration of laminar-boundary layer equations is included in Part II. A detailed analysis of boundary layer equations for an incompressible gas in the presence of injection for self-similar flows and for a flow with arbitrary velocity distribution on the outer edge of the boundary layer are presented. A general analogy between heat- and mass-transfer coefficients in a laminar multicomponent boundary layer is considered

The experimental investigations described in Part II are related mainly to ballistic facilities, their equipment, and the techniques and results obtained in the study of flows around bodies of various shapes in free flight. Two series of experiments are described: the first was designed for the accurate determination of aerodynamic coefficients of models in free flight, while the second was conducted to obtain recordings of flow spectra from which the location and shape of shock waves and other flow parameters can be deduced. The accuracy attained in drag coefficient measurements is of the order of 1%, and that of shock standoff distance, 5%. Several articles presented by I. I. Meshin, a leading specialist in ballistic research, and his coworkers are concerned with ballistic ranges, their instrumentation, and various techniques used for aerophysical investigation of supersonic gas flows past bodies of various shapes in free flight.

An approximate procedure for computing the velocity of a model accelerated by a light-gas gun and the results of a theoretical calculation of its main characteristics are presented by S. N. Palkin and I. I. Reznikov. The parameters of a given light-gas gun using hydrogen and helium are determined as an illustrative example. The relative merits of hydrogen and helium as driving gases are discussed.

The articles presented by V. G. Maslennikov are primarily concerned with the investigations of the position and shape of shock waves produced by the motion of bodies of various shapes at supersonic velocities (up to 2 km/sec) in gases with different intramolecular structure and with real gas effects taken into account. One of the articles describes a high-speed spark photography system with a rate of up to 40,000 frames per second.

Well-produced by Soviet standards, the book contains 279 illustrations; each article has an abundance of figures and diagrams and many have oscillogram recordings.

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